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Ocean circulation is shown to influence the bio-optical properties in open and coastal waters in the Gulf of Mexico. 3-dimensional physical ocean properties of temperature, salinity, and currents determined from the Navy Coastal Ocean Model (NCOM) are being combined with daily "latest pixel composite" satellite properties (phytoplankton, CDOM and detritus absorption and backscattering and SST). The coupling of these data sources provides supportive evidence of the degree which physical processes influence bio-optical processes in the surface ocean. NCOM assimilates daily SST along with synthetic temperature and salinity profiles from MODAS and is forced by surface COAMPS winds. Ocean color and SST from SeaWIFS and MODIS (Terra aqua) provide daily real-time observations.

We demonstrate the response of the Mississippi River plume (observed through bio-optical signatures), to coastal advection and eddy circulation. We observe that divergent and convergent regions in the model show a strong bio-optical response (growth and decay of phytoplankton) in the imagery. Furthermore, particle tracking in the model is used to follow different river discharges and track the corresponding bio-optical response in the imagery.

Using effective methods, these combined data sources provide new tools for coastal managers in assessing and predicting HABS, hypoxia and freshwater impacts.

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Author(s) Name(s) (*First,MI,Last*), *Code, Affiliation if not NRL*

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PHYSICAL AND BIO-OPTICAL PROCESSES IN THE GULF OF MEXICO – LINKING REAL-TIME CIRCULATION MODELS AND SATELLITE BIO-OPTICAL AND SST PROPERTIES*

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ABSTRACT

Ocean circulation is shown to influence the bio-optical properties in open and coastal waters in the Gulf of Mexico. Three dimensional physical ocean properties of temperature, salinity, and currents determined from the Navy Coastal Ocean Model (NCOM) are being combined with daily "latest pixel composite" satellite properties (phytoplankton, CDOM and detritus absorption and backscattering and SST). The coupling of these data sources provides supportive evidence of the degree which physical processes influence bio-optical processes in the surface ocean. NCOM assimilates daily SST along with synthetic temperature and salinity profiles from MODAS and is forced by surface COAMPS winds. Ocean color and SST from SeaWIFS and MODIS (Terra and Aqua) provide daily real-time observations.

We demonstrate the response of the Mississippi River plume (observed through bio-optical signatures), to coastal advection and eddy circulation. We observe that divergent and convergent regions in the model show a strong bio-optical response (growth and decay of phytoplankton) in the imagery. Furthermore, particle tracking in the model is used to follow different river discharges and track the corresponding bio-optical response in the imagery. The combined model and imagery analyses provide new methods to extend the limitations of models and imagery when analyzed individually. These include model validation of ocean features and extending the surface satellite properties to include subsurface processes. Lastly, we applied time inversion of particle tracking from the models to show the source waters where satellite observed phytoplankton blooms originated.

Using effective methods, these combined data sources provide new tools for coastal managers in assessing and predicting HABS, hypoxia and freshwaters impacts

1.0 INTRODUCTION:

Monitoring the ocean conditions on a real-time basis is becoming a reality as a result of the increased number of satellite data products and the ocean information become available from numerical models. Similar to what occured within the weather forcast systems in the 1950's, the ability to ocean forecast and monitor is occuring with the research and being trasitioned to the operational community. This capability is expanding as a result of our ability to fuse and combine these data sets together and provide increase awareness of how the ocean is responding to the physical and biological processes.

Increased satellite capability from SeaWIFS, MODIS (AQUA, and TERRA) and AVHRR satellite provide coverage of both coastal and open ocean conditions for monitoring the bio-optical properties and the SST. These satellites provide near real-time coverage of quantiative ocean properties based on the inter-calibration of sensors and algorithms. However, these sensors are still remain limited by cloud cover and inability to completely understand the ocean processes.

* Presented at the Eighth International Conference on Remote Sensing for Marine and Coastal Environments, Halifax, Nova Scotia, 17-19 May 2005.

Increased capability with numerical models at global and regional scales are available to define the nowcast and forcast of mesoscale ocean features and processes. These models have expanded to subnesting of models which can accurately define finer scales coastal processes well beyond the spatial and temporal scales of present satellite sensing tools.

The combined remote sensing and numerical models provide enhanced understanding of the ocean processes and provides a "window" toward the future capability for monitoring and forcasting ocean conditions. To a certain extent, our ability exists "now" for defining ocean conditions at regional scales. Remote sensing and numerical models work together to provide the character of the ocean. The limitations of the satellite coverage are mitigated by the increased temporal coverage from numerical models. Similarly, the validation and confidence of the model is enforced by similarities with satellite products. Correspondingly, the linkages of the satellite bio-optical processes as described by satellite products, can be better defined by how the physical circulation provided by models. The fusion of these data sets provide for the first time the ability to define how the physical ocean propeties can control the biological, gelogical and optical processes in the ocean.

Our objective is to define how biological, optical and SST properities defined by satellites in the Gulf of Mexico are partially controlled by the physical circulation as defined by numerical models. We will provide example of the time series of these fused data sets to demonstrate the enhanced capability for monitoring the ocean processes.

2.0 SATELLITE DATA

The examples used will be from MODIS Terra and Aqua data collected and processed in near realtime at 1 km resoltuion (Arnone and Parsons.) Currently, there are approximatly 2 daytime passed per day at ~ 0930 and 1430 from Terra and Aqua, and 2 night time passes. These data are processed using the NRL, Automated Processing System (APS) software which is an extension of the NASA – Goddard SeaDAS software. The data are automatically calibrated, atmosperhic corrected and in-water optical products of the inherent optical properties using the quasi analytical algortihms (QAA) and chlorophyl (OC3) and sea surface temperature products are produced. (Lee et al. 2003, Arnone and Parsons 2004). These products are registored to a Mercator projection. The IOP products include 1) backscatter at 550 nm provides estimated of the number of partical scattering from both the suspended inorganic and organic (phytoplantkon) 2) total absorption coefficient at 443 nm which defines all absorption components such as phytoplanton (aphi), detritus (adet) and colored dissolved orgainic matter (CDOM).

A seven day latest pixel composte image is created for each day to help remove cloud cover and bad pixel coverage. The most recent valid pixel is used for each day which extend backward for 7 day. Pixels that are invalid represent no coverage for the last 7 days. This technique proved to provide the best image for a given day and can be used to characterize the ocean processes and mesoscale features.

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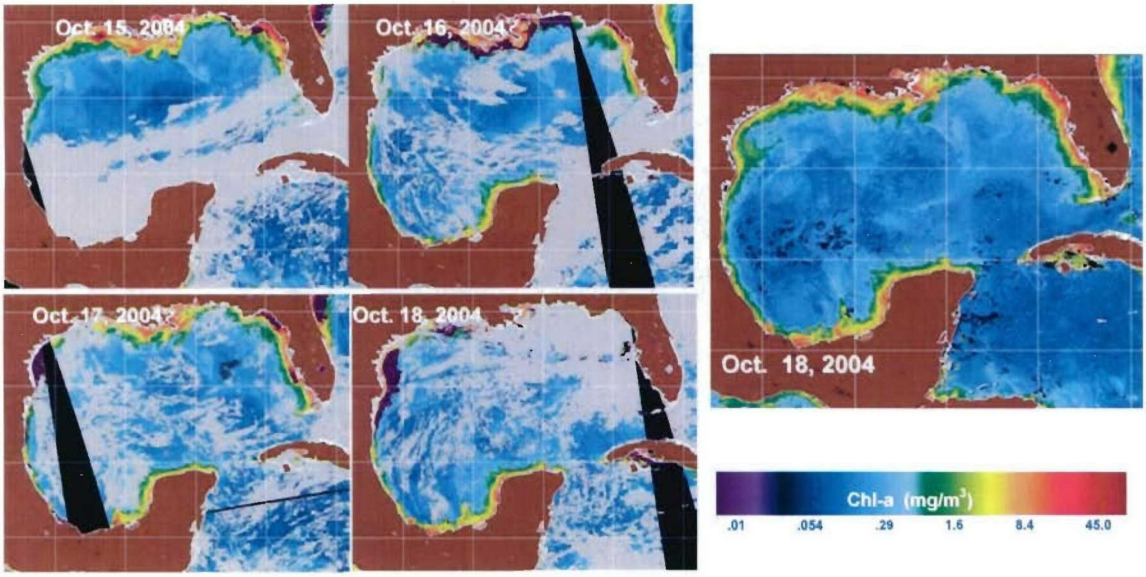

Figure 1: Example of the seven day latest pixel compositing method for removal of clouds and defining mesoscale ocean features

3.0 NUMERICAL MODEL – NAVY COASTAL OCEAN MODEL

Satellite ocean properties are combined with surface currents from the Naval Coastal Ocean Model (NCOM) (Martin, 2000) to characterize how the physical circulation influences the chlorophyll signatures observed. Ocean models also have advanced significantly within the last five years and provide methods to understand a variety of coastal processes at different resolutions. The Intra-America Seas NCOM coastal model uses a horizontal grid resolution of 1/24 degree (~6 km) and 41 vertical sigma-z levels. The 3-hourly atmospheric heat fluxes, solar radiation, wind stresses, and surface pressure fields generated by the U.S. Navy's mesoscale atmospheric model, the Navy Coupled Ocean Atmosphere Prediction Systems (COAMPS®), drive the system. Open boundary conditions, including sea surface elevation, transport, temperature, salinity and currents, are provided by the NRL-SSC 1/8-degree Global NCOM model. The monthly freshwater discharge from 53 rivers is included in NCOM. The nowcast and predicted variables include a time series of sea surface height, temperature, salinity, and currents in four dimensions that are combined with real-time satellite image properties of the physical and bio-optical properties (Ko et al., 2003).

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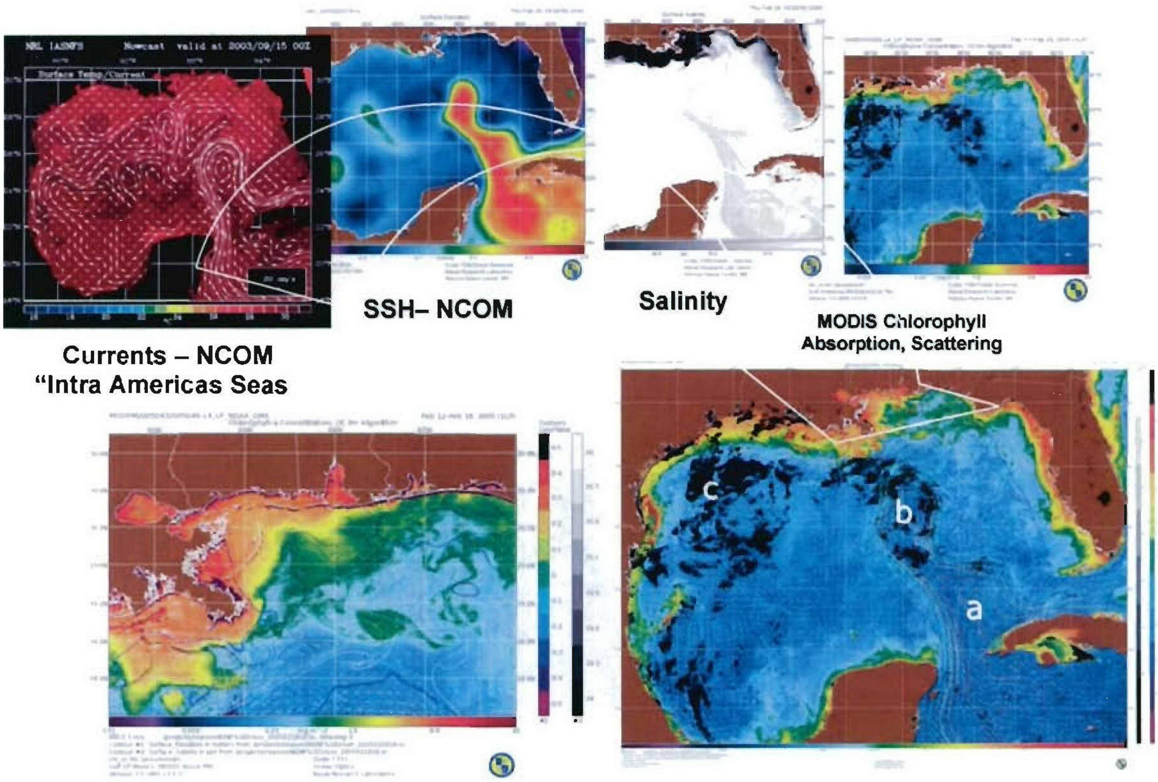

Figure 2: The fusing of the NCOM model with the satellite optical properties are illustrated for a single day. The NCOM surface currents, sea surface heights and the surface salinity are overlaid with the MODIS latest pixel composite of the chlorophyll. Note locations of A) Loop current B) spin off eddy C) clouds

4.0 RESULTS

A sequence of model and remote sensing products from July 1 through August 17 2003 illustrate the response of the chlorophyll to the separate of the loop current from a warm core eddy. The ocean color imagery shows variability of the patches of the surface chlorophyll. With the overlay of the surface currents from NCOM, the location of the Loop current and the development of a warm core eddy (b) suggest that the chlorophyll bloom is responding the divergence of the current field. Also shown in the sequence are the changes in the Mississippi River Plume dispersion along the Gulf Coast as the warm core eddy interacts with the coast. The influence of offshore mesoscale eddies on coastal regions is illustrated in the SeaWIFS image for Dec 18, 2003 Figure 4. The MS Plume is advected to the west to the south of the delta by a cyclonic eddy (a) North of the delta, the coastal waters are advected eastward by the surface currents. The surface currents clearly are linked to the observed changes in the surface chlorophyll.

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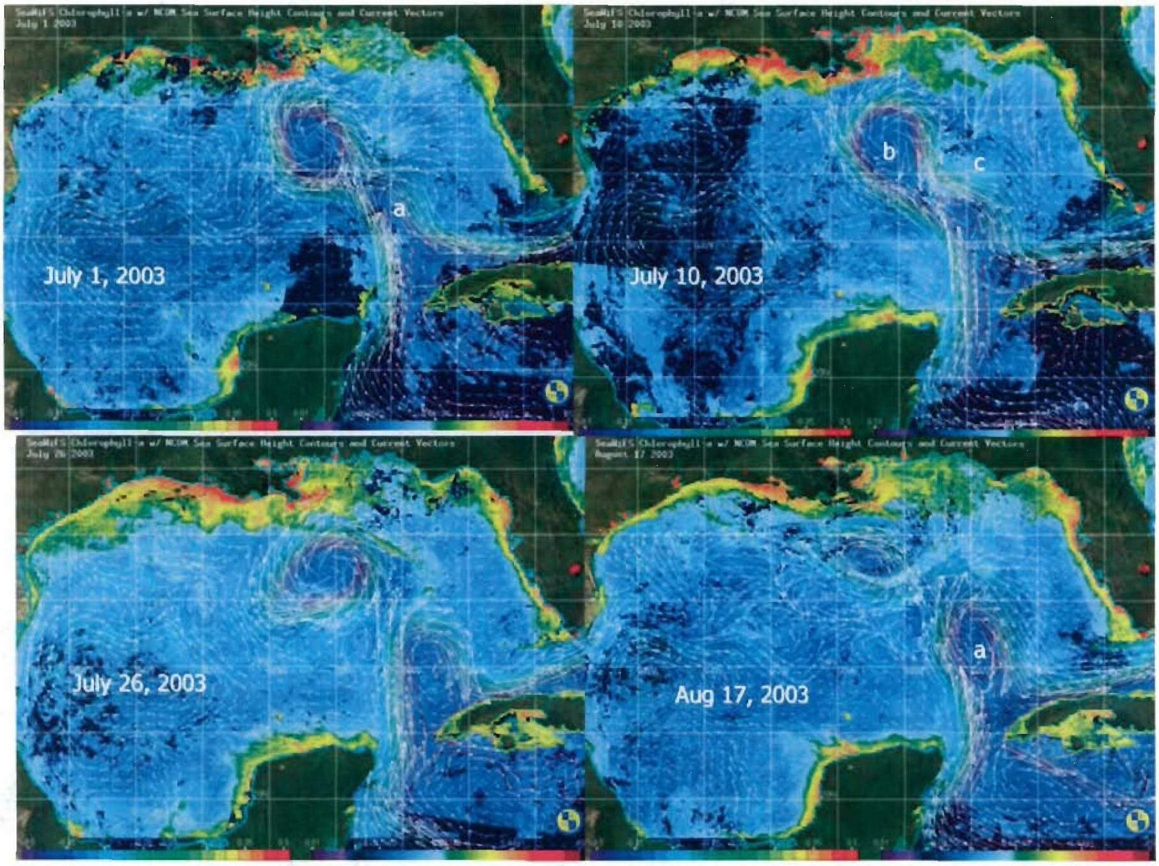

Figure 3 – Illustrates the response of the satellite biological properties in response to the mesoscale ocean features. A) Loop current b) warm core eddy c) high chlorophyll in response the surface divergence.

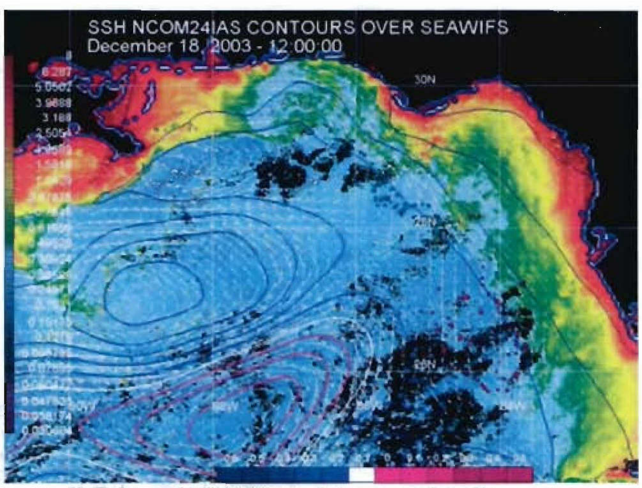

Figure 4- The SeaWIFS chlorophyll field and NCOM model are used to illustrate how coastal currents help define the chlorophyll distribution in coastal areas. The SSH are shown in the contours and the white and red dots represent particle that were seeded in the model.

* Presented at the Eighth International Conference on Remote Sensing for Marine and Coastal Environments, Halifax, Nova Scotia, 17-19 May 2005.

5.0 SUMMARY

The fusing of satellite biological and SST products with numerical model surface circulation provides new understanding of ocean processes. The large-scale mesoscale rings and eddies play key roles in the locations of biological blooms. Additionally, these mesoscale features strongly influence the coastal biological and optical conditions. The locations of features in satellite images can be explained by understanding the physical circulation processes.

The results presented illustrate that the models provide reasonable expectations of the physical oceanography and can be qualitatively validated using the satellite surface properties.

The fusing of these remote sensing and modeling data products provides a synergetic approach toward characterizing the ocean weather. Future developments in ocean forecasting and monitoring coastal conditions will require using these extensive data sets for assimilation.

6.0 REFERENCES

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